X/47

Release 10/80

INSTRUCTION MANUAL

Model 71

MEASUREMENTS CORPORATION

BOONTON X/47 NEW JERSEY

X/47

INSTRUCTION BOOK
MODEL 71
SQUARE WAVE GENERATOR

The Model 71 Square Wave Generator is a completely self-contained source of square waves covering the fundamental range of 6 to 100,000 cycles per second. This makes it suitable for testing characteristics of many types of amplifiers and networks over the range from one cycle to several megacycles per second, covering the usual audio and video ranges.

The usefulness of square waves for determining the phase and frequency characteristics of networks depends upon the fact that these characteristics are completely determined if the response of the network to the application of the unit function of voltage is known.

Square waves are merely the unit function of voltage, cyclically repeated at suitable time intervals. Thus the response of the network to the unit function also repeats cyclically, and by placing the output wave upon the deflecting plates of an oscilloscope, direct observation of the response against time is obtained, and the characteristics of the network thus obtained by direct observation and interpretation of the pattern seen. Roughly speaking, the application of a square wave of repetition frequency (f) allows direct determination of the frequency characteristics of the network down to a frequency of f/10 and up to a frequency of f x 10, sometimes higher. Thus the usual audio frequency network can be tested completely over the range 5 cycles to 20 or more kilocycles by the application of only two different square wave frequencies, say 50 cycles and 2 kilocycles. Testing of video networks is greatly simplified particularly since phase relationships can be determined more conveniently and rapidly by the square wave technique than by any other known method.

The interpretation of the pattern seen on the oscilloscope screen in terms of actual phase and frequency characteristics is a matter requiring some experience, since some of the relationships are not immediately obvious from the pattern. It is true, however, that all of the information which may be desired about the action of any circuit is contained in the output wave pattern, and is available to the observer who knows what to look for; therefore, including not only the more commonly known and measured characteristics, but also others less easily measured and hence not commonly appreciated. The increased speed of obtaining the result, as well as the greatly increased amount of information about the circuit which is made available by the square wave technique, will pay any technician handsomely if he will take the time to learn the technique and to become experienced in interpreting the results obtained.

This is particularly true in the television field, but even in the audio frequency field it is becoming evident that certain phase and transient relationships commonly neglected may have an important bearing on the overall fidelity and naturalness of reproduction of sound systems. These relationships are difficult to determine by sine wave testing methods, but become simple in the square wave testing technique.

One important distinction between the sine wave and the square wave technique which must be kept in mind is that, in sine wave testing amplitudes are of prime importance and must, therefore, be measured, thus requiring at least two meter readings at each frequency of measurement. In the square wave method the answer is obtained by the interpretation of wave shape, not of ampltiude, as long as no overload is encountered. Thus no measurements of amplitude are required, no meters need to be set or read and no expensive attenuation systems are required. The Model 71 is definitely not a standard of amplitude, even though for convenience it includes an output meter and a calibrated attenuator. These are meant to supply only an approximate idea of output voltage and a convenient method of varying this voltage, and are not standards of voltage or attenuation. The resistors used in the attenuator are adjusted only to within 5% of their nominal values, thus permitting a considerable economy in manufacturing and a consequent reduction of the price of the instrument. More complicated and accurate attenuation systems can be included on special order, for those special cases where they may become necessary, but the standard system should suffice for most users.

The same considerations are true to some extent of the oscillator which determines the fundamental frequency in the Model 71. Since no very accurate knowledge of the frequency of test is usually required in the square wave technique, no attempt has been made to make the Model 71 an accurate standard of frequency. The frequency dials are individually calibrated to eliminate possible manufacturing differences in the variable resistors which are the frequency determining elements, but since these variable resistors are subject to possible change over their life and to short time changes due to temperature and humidity, no guarantees as to frequency accuracy can be made. To overcome this in cases where it is considered a disadvantage, terminals have been provided by means of which a locking or synchronizing voltage may be injected into the oscillator circuit, so that the frequency can be stabilized by being made equal to an external frequency or to some harmonic or submultiple thereof.

The frequency-determining oscillator is of the relaxation or multivibrator type, using two 6J5 tubes. Coarse variation of frequency is obtained by changing the feedback condensers

in 10:1 steps; the switch which accomplishes this is the lower left control dial on the instrument panel. The four steps of capacitance included in the standard instruments provide nominal ranges of 5-100, 50-1000, 500-10,000 and 5000-100,000 cps; the fine variation in each range is obtained by a dual variable resistor in the grid circuits of the oscillator tubes, controlled by the upper left control dial on the panel. This range of fundamental frequencies should cover all normal testing requirements, but if an extension is needed for special requirements, higher or lower frequency ranges can be readily added by connecting appropriate condensers to unused switch positions, as will be evident from the circuit diagram attached to this instruction book.

The output wave of the multivibrator type oscillator has the essential characteristic of square waves, the extremely short "flip-over" period between the positive and negative half-cycles. The tops of the waves are not flat, but this can be remedied by arranging the output stage to be driven from cutoff on one side of the cycle to grid saturation on the other, thus flattening the tops. However, it is possible to improve performance in respect to short rise time and flatness of tops if an intermediate buffer-clipper stage is employed between the oscillator and output stages, and this stage has been included in the Model 71. The output of this 6J5 stage is a square wave of about 60 volts peak amplitude, short rise time, and almost perfectly flat top, which when applied to the output stage and improved by the further clippings in this stage emerges as a square wave of almost ideal characteristics.

The rise time of all Model 71's having serial numbers over #641 is approximately 0.08 microseconds for outputs under 5 volts. (Older Model 71's can be serviced and modernized, if short rise time is of importance). This result is obtained largely through the use of the high-conductance 6AG7 tubes in this stage; such high-frequency cutoff as is indicated by this rise time is due in large part to the unavoidable capacitance of the output circuits shunting the output resistance of 1500 ohms. For fastest rise time the center output knob must be adjusted for optimum, not necessarily at the 1.0 mark. Some older 6AG7 tubes may exhibit a small amount of overshoot after a short period of use and must be replaced. Recent production 6AG7's are better in this respect. Some improvement of the steepness of the wave front can be obtained by reducing the output impedance by shunting, at a sacrifice of output voltage since the output stage operates on a constant-current basis. This shunting can be done externally very readily at any time desired, hence no provision has been made in the standard instruments for it. The standard output impedance is 20 ohms per volt peak output, as will be evident from the circuit diagram, or 1500 ohms.

Attenuation of this maximum voltage is provided for only one side of the output circuit by a simple voltage-divider type of attenuator. The voltage appearing across this attenuator is measured by a simple d.c. voltmeter circuit, the use of which is made possible by the characteristics of the square waves. Since current is flowing in the output tube during only half the cycle, the tube being cut off during the other half, current will flow through the voltmeter during only half the cycle, and always in the same direction. Thus the voltmeter will indicate just one-half of the peak voltage, and it is calibrated so that at the 1.0 point on its scale, indicating 75 peak volts of output, it is actually indicating 37.5 volts d.c. It will be evident that this relationship depends upon exact equality between the two half cycles of the applied wave, and that any inequality will result in an error of indication. Such inequalities can result from differences between the two oscillator tubes, between the two feedback condensers, or between the two variable grid resistors and by careful selection of components at the factory these differences are largely eliminated.

As mentioned above, the inclusion of the buffer-clipper stage considerably improved the performance of the square wave generating system. However, it introduced problems of coupling the various stages together; it was found that the usual condenser and resistor coupling circuits made it impossible to obtain the quality of performance desired for this instrument, even if the fundamental frequency range were greatly reduced. The design was, therefore, carried through on a direct coupling basis, with no coupling networks of any sort between the stages to introduce frequency discrimination. As a result, the amplification system of the Model 71 produces square waves having perfectly flat tops, even at very low fundamental frequencies. Frequencies as low as one cycle in several seconds have been obtained in experimental models, with no decrease of flatness of tops and very little increase in the rise time, thus approaching very closely the theoretical ideal unit function (sometimes called Heaviside Unit Function).

This ideal flatness of top would be lost if it were necessary to include any coupling circuits between the output tubes and the equipment under test. Therefore, no series condensers are used, and in order to prevent the B supply voltage from appearing at the output terminals, the entire supply voltage system is reversed from conventional practice, the positive terminal being grounded and the tube cathodes all being at high negative potential. This departure is emphasized in the circuit diagram by inverting all of the circuit elements diagrammatically, placing the negative leads at the top of the figure and the ground positive busses at the bottom.

It will be seen that this arrangement will not produce from the single-ended connection obtained between one tube and ground, a square wave whose axis is at ground potential. Rather, one peak of the wave is at ground, being generated when

the output tube is on its cutoff half cycle; the other half of the wave being negative to ground by the whole peak value of the wave, being generated when the tube is on its conducting half cycles.

Thus the output wave produced by the single-ended connection is all negative to ground or, in more conventional terminology, it contains a d.c. component equal to half its peak-to-peak value, and negative in sign. In those cases where this d.c. component is significent, it can be altered or removed by means of a series bucking battery, or by means of a large series condenser in some applications. No series condenser should ever be included, however, unless consideration of the load into which it works shows that no considerable low-frequency discrimination will be introduced.

In addition there has been included in the Model 71 a 6SA7 modulator stage for applying "square wave modulation" to a carrier. There are present in the output circuit of this modulator not only the carrier and its sidebands to make up the "square wave modulation" but also the "d.c. component" of modulator plate current. A portion of the square wave which is 180° out of phase with this "d.c. component" is applied to "buck out" this undesired modulation product. The knob under the output meter, which is used to adjust the output over a limited range, also acts as a balancing control. If the square wave modulated carrier is viewed on a wide range oscilloscope, this control places the axis in the center of the carrier envelope. There remains a "d.c." switching transient which does cause some trouble from shock exicitation when working with very low level carriers.

It is recommended that this modulator be operated with .1 to 1 volts of r.f. into the 6SA7 and attenuation be secured after the application of the square wave modulation in order to minimize the effects of shock excitation by this "d.c." switching transient. A simple test for the presence of patterns arising from this "d.c." switching transient is to decrease the applied carrier to zero and note whether there is any residual pattern. This residual would likely consist of a series of short damped wave trains. If no residual is present, the switching transient is not a source of confusing patterns and the carrier can be again applied and the square wave modulation pattern examined for assymetry, rounded corners, overshoot, etc.

It is recommended that the following references be studied for a more comprehensive understanding of the fundamentals of square wave testing.

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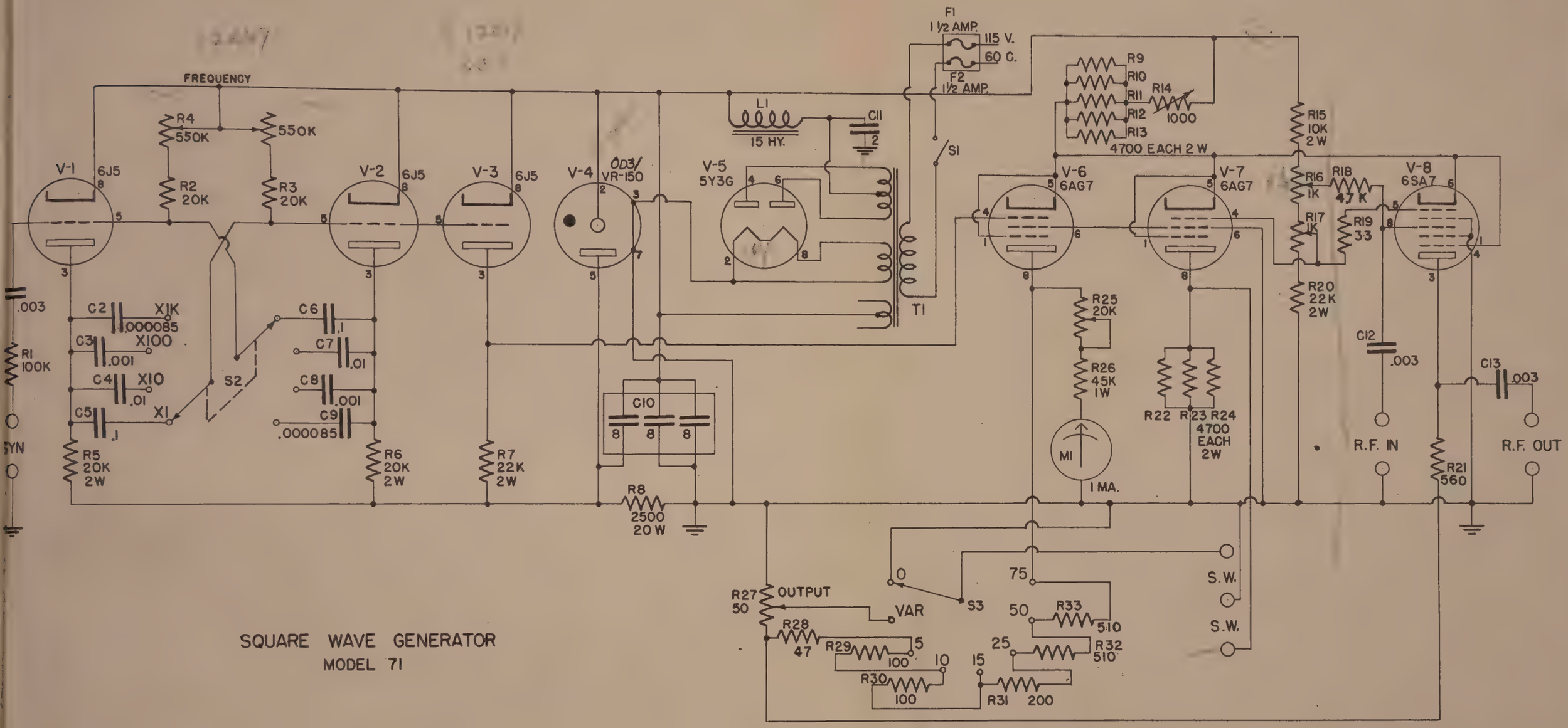
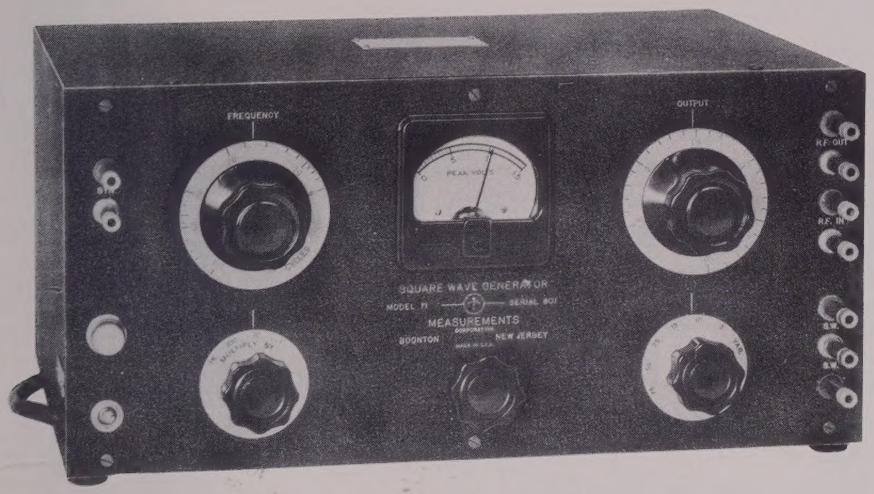


SQUARE WAVE GENERATOR
MODEL 71

UNLESS OTHERWISE NOTED:
ALL CAPACITANCES IN MICRO-FARADS.
ALL RESISTANCES IN OHMS.
ALL FIXED RESISTORS ½ WATT.

SQUARE WAVE GENERATOR
Model 71



Since 1939, the Model 71 Square Wave Generator has been widely used for many different applications in the development of AM, FM and TV equipment. Its expert design and proven performance has made it a popular instrument in Measurements' line of Laboratory Standards.

With the Model 71, performance characteristics of audio, video and r.f. amplifiers may be quickly determined by observing wave shapes on a cathode-ray oscilloscope. Varying the frequency of the square wave expands or compresses the time base thus permitting observation of both rise time and overshoot of the front of the wave or its top slope or decay time. Rapid alignment of wide-band i.f. amplifiers is made possible by the employment of the square wave technique.

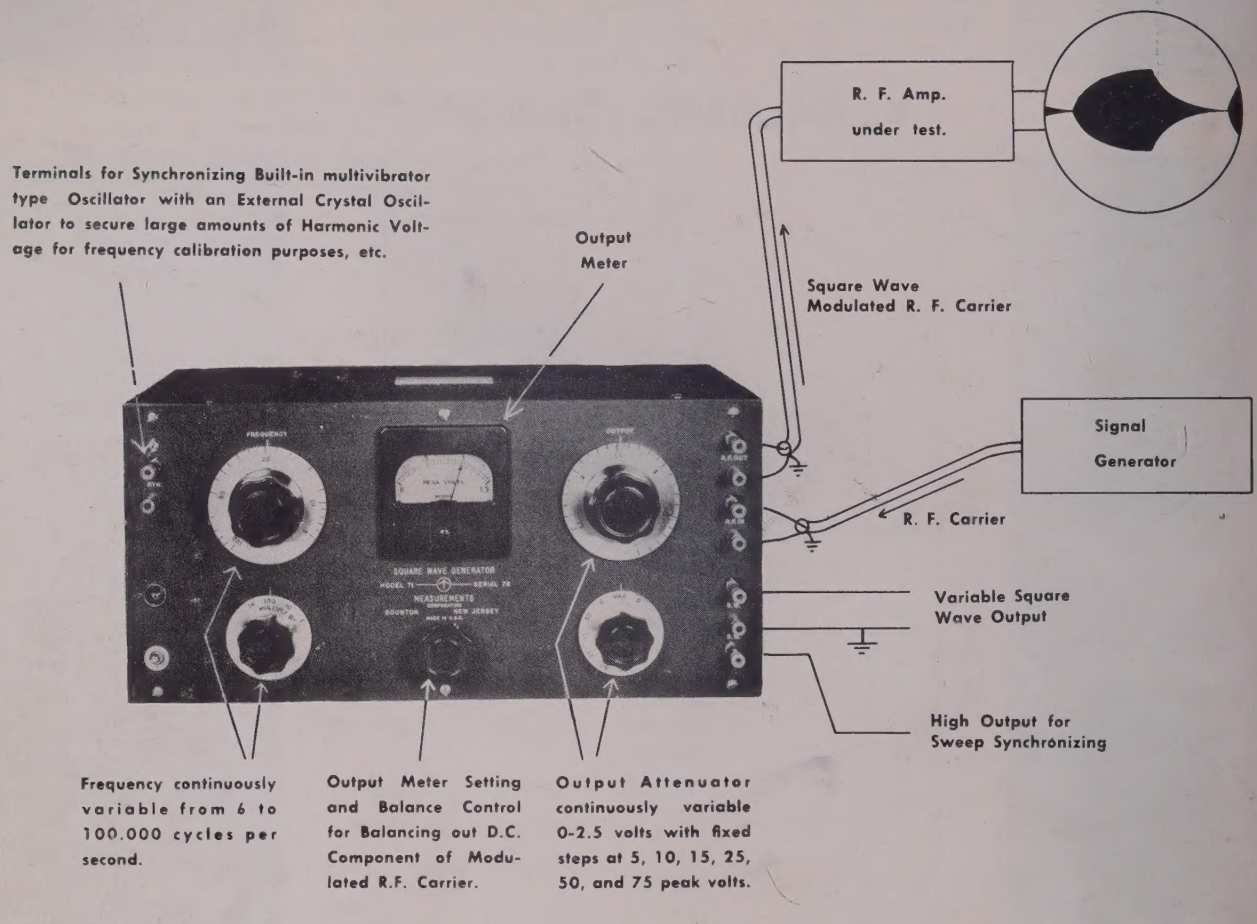
The Model 71 contains a built-in, multi-vibrator type oscillator providing its own frequency source, which may easily be locked with a sine-wave or other external source when frequency accuracy is important. A variable attenuator is supplied to reduce output voltage to the desired value.

An r.f. modulator is provided so that square envelopes of r.f. energy may be used to measure the characteristics of r.f. and i.f. amplifiers. The Model 71 may be used to check amplitude, phase, frequency and transient response on all types of amplifiers. It is compact and self-contained and will prove to be an estimable time-saver wherever square wave analysis is employed.

MEASUREMENTS CORPORATION

BOONTON NEW JERSEY

Model 71 Square Wave Generator


Terminals for Synchronizing Built-in multivibrator type Oscillator with an External Crystal Oscillator to secure large amounts of Harmonic Voltage for frequency calibration purposes, etc.
Output Meter
R. F. Amp. under test.
Square Wave Modulated R. F. Carrier
Signal Generator
R. F. Carrier
Variable Square Wave Output
High Output for Sweep Synchronizing
Frequency continuously variable from 6 to 100,000 cycles per second.
Output Meter Setting and Balance Control for Balancing out D.C. Component of Modulated R.F. Carrier.
Output Attenuator continuously variable 0-2.5 volts with fixed steps at 5, 10, 15, 25, 50, and 75 peak volts.

SPECIFICATIONS:

FREQUENCY RANGE:
Continuously variable from 6 to 100,000 cycles per second.

WAVE SHAPE:
Rise time less than 0.2 micro-seconds with negligible overshoot at 75 peak volts output. At 5 volts or less rise time is less than 0.1 microseconds.

OUTPUT VOLTAGE:
Step attenuator giving 75, 50, 25, 15, 10, 5 peak volts fixed and 0 to 2.5 volts continuously variable.

OUTPUT IMPEDANCE:
20 ohms per volt.

SYNCHRONIZING OUTPUT VOLTAGE:
25 volts peak.

SYNCHRONIZING OUTPUT IMPEDANCE:
1500 ohms.

SYNCHRONIZING INPUT IMPEDANCE:
Over 20,000 ohms.

R.F. MODULATOR:
5 volts maximum carrier input. Translation gain is approximately 0.1. Output impedance is 600 ohms.

TUBES:
Two 6AG7's; three 6J5's; one 6SA7; one OD3/VR150; one 5Y3G.

POWER SUPPLY:
117 volts, 50/60 cycles. Self-contained, no batteries. 100 watts.

DIMENSIONS:
7" high, 15" wide, 7½" deep.

NET WEIGHT:
Approximately 20 lbs.

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Printed in U.S.A.

Form 127 - 10M - 5-51

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